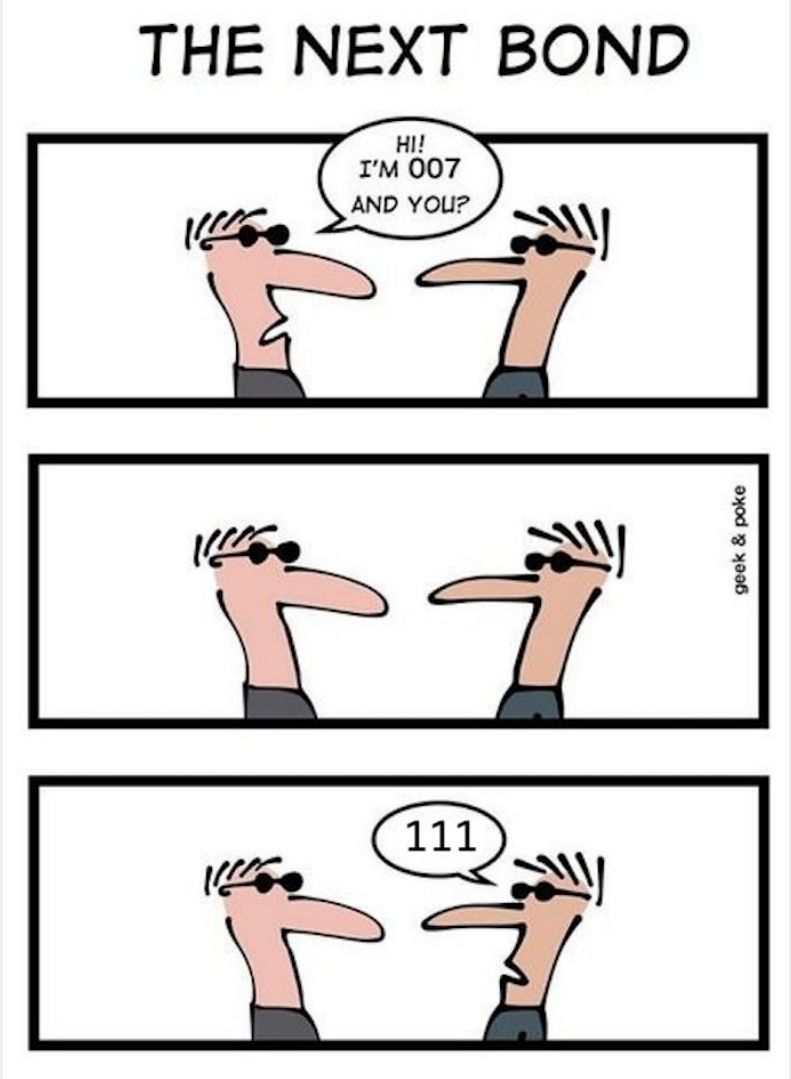
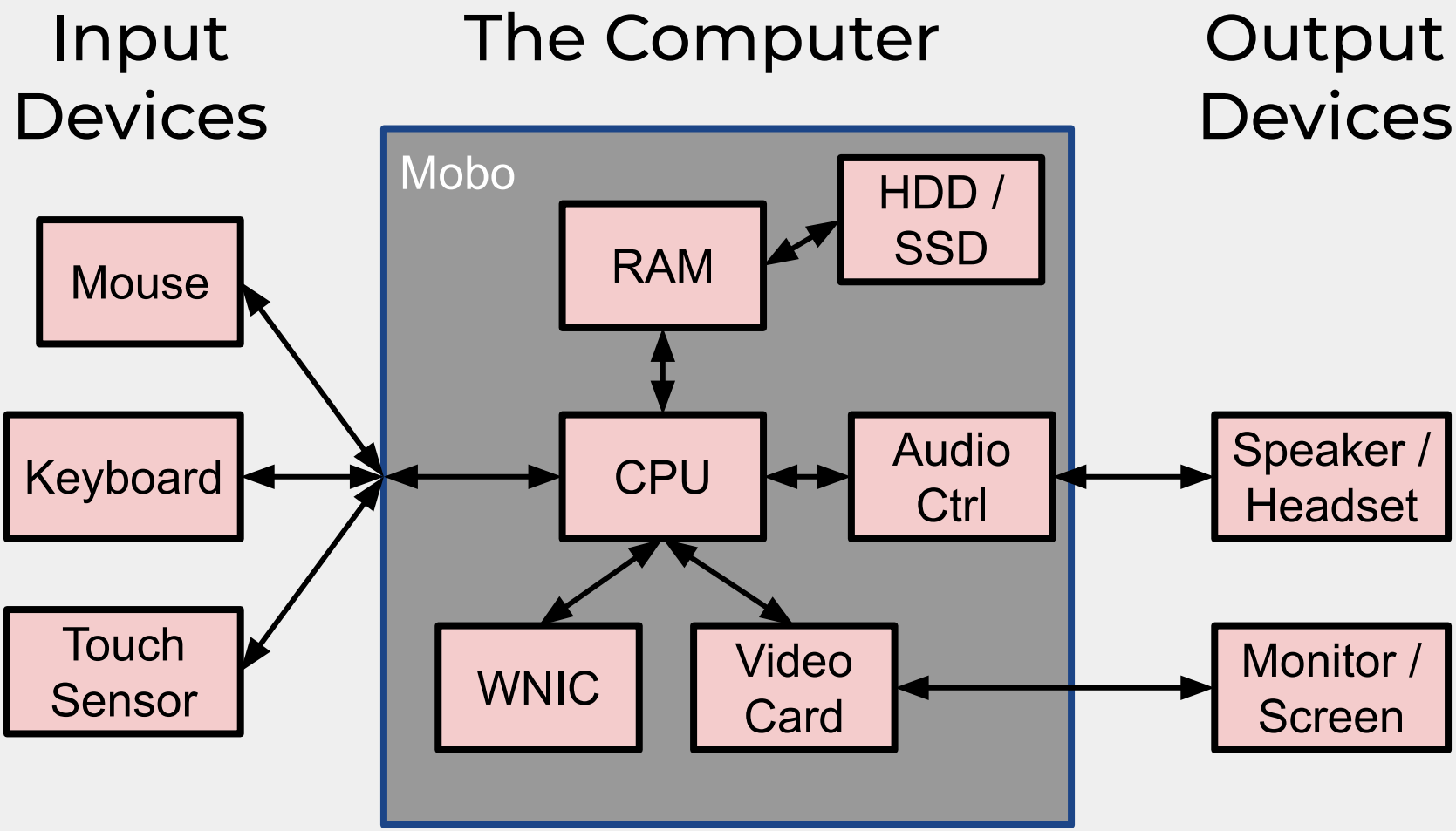
# CS 110
# Binary

Benjamin Dicken




Input Devices
The Computer
Output Devices
Mobo
Mouse
Keyboard
Touch Sensor
RAM
HDD / SSD
CPU
Audio Ctrl
WNIC
Video Card
Speaker / Headset
Monitor / Screen

# Representing Information

- Computers store information on Hard Drive Disk (HDD) and/or SSD (Solid State Drive)
  - Both HDDs and SSDs are types of ***Hard Drives***
- They also store information on RAM
- Use ***Binary***
- This means that computers can only use ***1s*** and ***0s*** for storing information
  - This includes words, images, programs, etc

# Representing Information

- One common type of hard drive today is the SSD (Solid State Drive)
- As solid state drive uses tiny electrical components called ***floating gate transistors (FGT)*** to store each 1 and zero
- A single SSD can have millions, billions, or even trillions of ***FGTs*** in them

# Representing Information

- How many bits (1’s and zeros) can a 500 gigabyte hard-drive store?

# Representing Information

- How many bits (1’s and zeros) can a 500 gigabyte hard-drive store?

**4,294,967,296,000**

01001000 01101111 01110111 00100000
01100100 01101111 01100101 01110011
00100000 01100010 01101001 01101110
01100001 01110010 01111001 00100000
01110111 01101111 01110010 01101011
00111111

# How does binary work?

# Storing things in Binary

Spend some time thinking and develop a methodology of translating **English letters** to **only 1s and 0s**.

How would you go about it?

# Storing things in Binary

Spend some time thinking and develop a methodology of translating **A Video** to **only 1s and 0s.**

How would you go about it?

# Representing Information

- ***Decimal*** (also called ***base-10***) is the numeric representation that most here are used to
  - In decimal, there are ***ten digits*** to use for representing numeric values: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9
- ***Binary*** (also called ***base-2***) is just another way of representing numbers
  - In binary, there are ***two digits*** to use for representing numeric values: 0, 1

# Representing Information

When we count in ***decimal***

| | | | |
|---|---|---|---|
| 0 | 7 | 14 | 21 |
| 1 | 8 | 15 | 22 |
| 2 | 9 | 16 | ... |
| 3 | 10 | 17 | |
| 4 | 11 | 18 | |
| 5 | 12 | 19 | |
| 6 | 13 | 20 | |

When we count in ***binary***

| | |
|---|---|
| 0 | 111 |
| 1 | 1000 |
| 10 | 1001 |
| 11 | 1010 |
| 100 | 1011 |
| 101 | 1100 |
| 110 | 1101 |

. . . . .

# Count

Using the counting technique to determine what the binary representation of the value **19** would be

No computers!

# Count

Using the counting technique to determine what the binary representation of the value **223** would be

No computers!

# Representing Information

- For every binary number, there is an equivalent decimal number
- When computers retrieve, process, modify, and store information, uses binary representation (ignoring quantum)
- When we talk about information being represented by numbers we will often refer to a ***decimal*** number, but the computer is really using ***binary*** internally

# Converting from Decimal To Binary

# Converting from Decimal To Binary

$2^7$ $2^6$ $2^5$ $2^4$ $2^3$ $2^2$ $2^1$ $2^0$

# Converting from Decimal To Binary

| $2^7$ | $2^6$ | $2^5$ | $2^4$ | $2^3$ | $2^2$ | $2^1$ | $2^0$ |
|---|---|---|---|---|---|---|---|
| = | = | = | = | = | = | = | = |
| 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 |

# Converting from Decimal To Binary

| $2^7$ | $2^6$ | $2^5$ | $2^4$ | $2^3$ | $2^2$ | $2^1$ | $2^0$ |
|---|---|---|---|---|---|---|---|
| = | = | = | = | = | = | = | = |
| **128** | **64** | **32** | **16** | **8** | **4** | **2** | **1** |

***Convert 147 to binary***

# Converting from Decimal To Binary

| $2^7$ | $2^6$ | $2^5$ | $2^4$ | $2^3$ | $2^2$ | $2^1$ | $2^0$ |
|---|---|---|---|---|---|---|---|
| = | = | = | = | = | = | = | = |
| 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 |

***Convert 147 to binary***

**147-128 = 19**

# Converting from Decimal To Binary

| $2^7$ | $2^6$ | $2^5$ | $2^4$ | $2^3$ | $2^2$ | $2^1$ | $2^0$ |
|---|---|---|---|---|---|---|---|
| = | = | = | = | = | = | = | = |
| **128** | **64** | **32** | **16** | **8** | **4** | **2** | **1** |

***Convert 147 to binary***

**147-128 = 19** **19-16 = 3**

# Converting from Decimal To Binary

| $2^7$ | $2^6$ | $2^5$ | $2^4$ | $2^3$ | $2^2$ | $2^1$ | $2^0$ |
|---|---|---|---|---|---|---|---|
| = | = | = | = | = | = | = | = |
| **128** | **64** | **32** | **16** | **8** | **4** | **2** | **1** |

***Convert 147 to binary***

**147-128 = 19** **19-16 = 3** **3-2 = 1**

# Converting from Decimal To Binary

| $2^7$ | $2^6$ | $2^5$ | $2^4$ | $2^3$ | $2^2$ | $2^1$ | $2^0$ |
|---|---|---|---|---|---|---|---|
| = | = | = | = | = | = | = | = |
| **128** | **64** | **32** | **16** | **8** | **4** | **2** | **1** |

***Convert 147 to binary***

**147-128 = 19** **19-16 = 3** **3-2 = 1** **1-1 = 0**

# Converting from Decimal To Binary

| $2^7$ | $2^6$ | $2^5$ | $2^4$ | $2^3$ | $2^2$ | $2^1$ | $2^0$ |
|---|---|---|---|---|---|---|---|
| = | = | = | = | = | = | = | = |
| 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 |

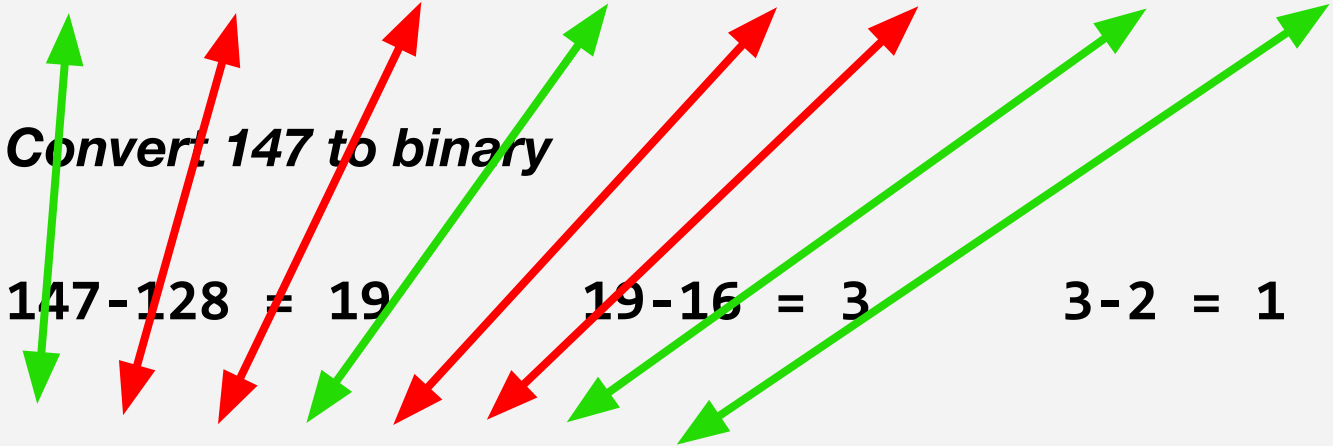
***Convert 147 to binary***

**147-128 = 19** **19-16 = 3** **3-2 = 1** **1-1 = 0**

**1 0 0 1 0 0 1 1**

# Converting from Decimal To Binary

| $2^7$ | $2^6$ | $2^5$ | $2^4$ | $2^3$ | $2^2$ | $2^1$ | $2^0$ |
|---|---|---|---|---|---|---|---|
| = | = | = | = | = | = | = | = |
| 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 |



***Convert 147 to binary***

147-128 = 19 19-16 = 3 3-2 = 1 1-1 = 0

**1 0 0 1 0 0 1 1**

# Convert to Binary

- Middle: **171**
- Sides: **98**

# Convert to Binary

- Middle: **171** **10101011**
- Sides: **98**

# Convert to Binary

- Middle: **171** **10101011**
- Sides: **98** **01100010**

# How do we go from binary to decimal?

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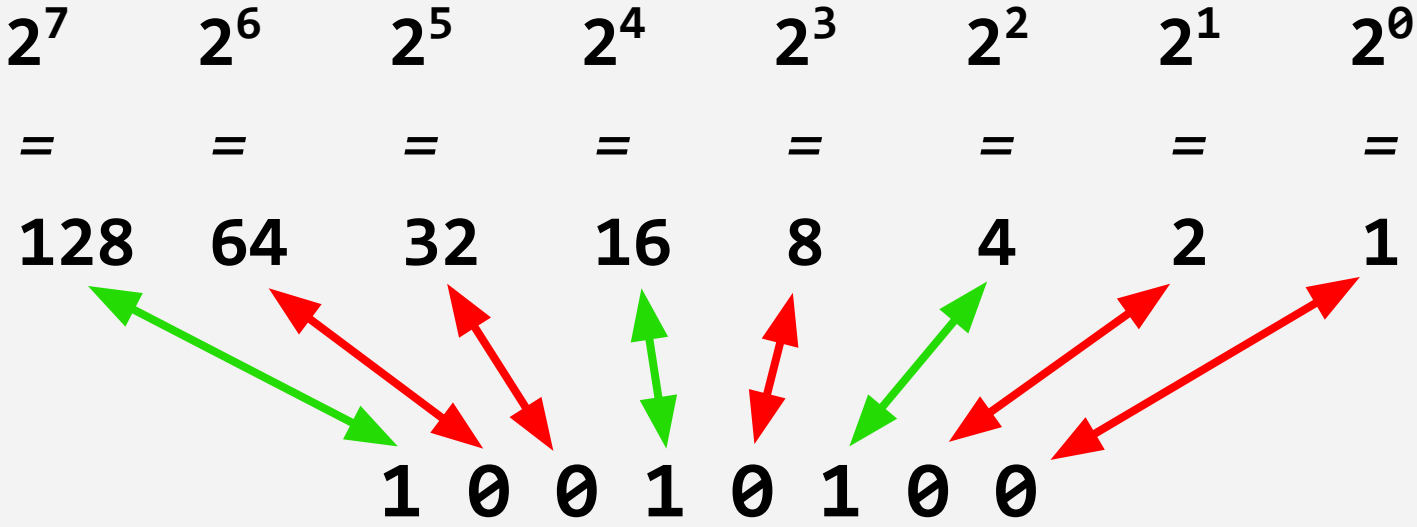
**1 0 0 1 0 1 0 0**

# How do we go from binary to decimal?

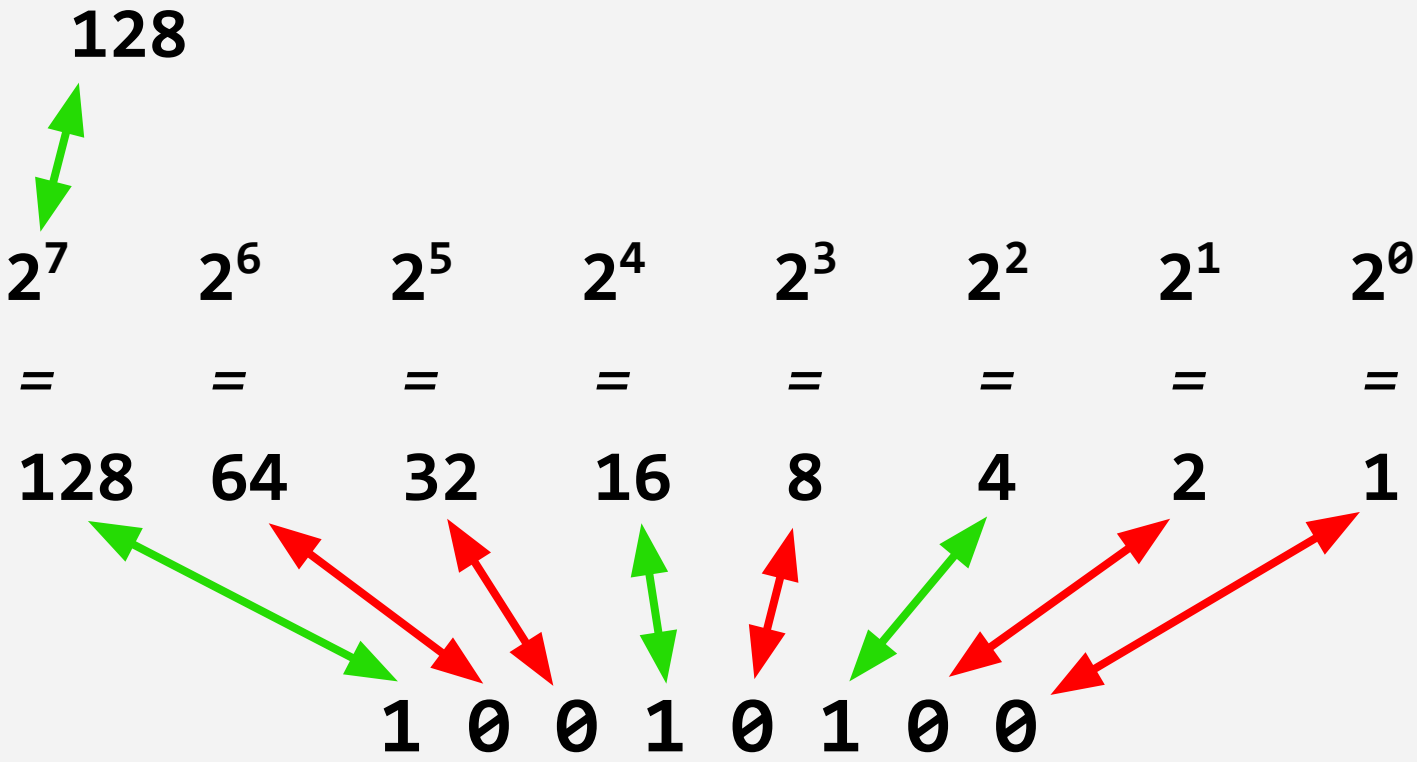
| $2^7$ | $2^6$ | $2^5$ | $2^4$ | $2^3$ | $2^2$ | $2^1$ | $2^0$ |
|---|---|---|---|---|---|---|---|
| = | = | = | = | = | = | = | = |
| 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 |

**1 0 0 1 0 1 0 0**

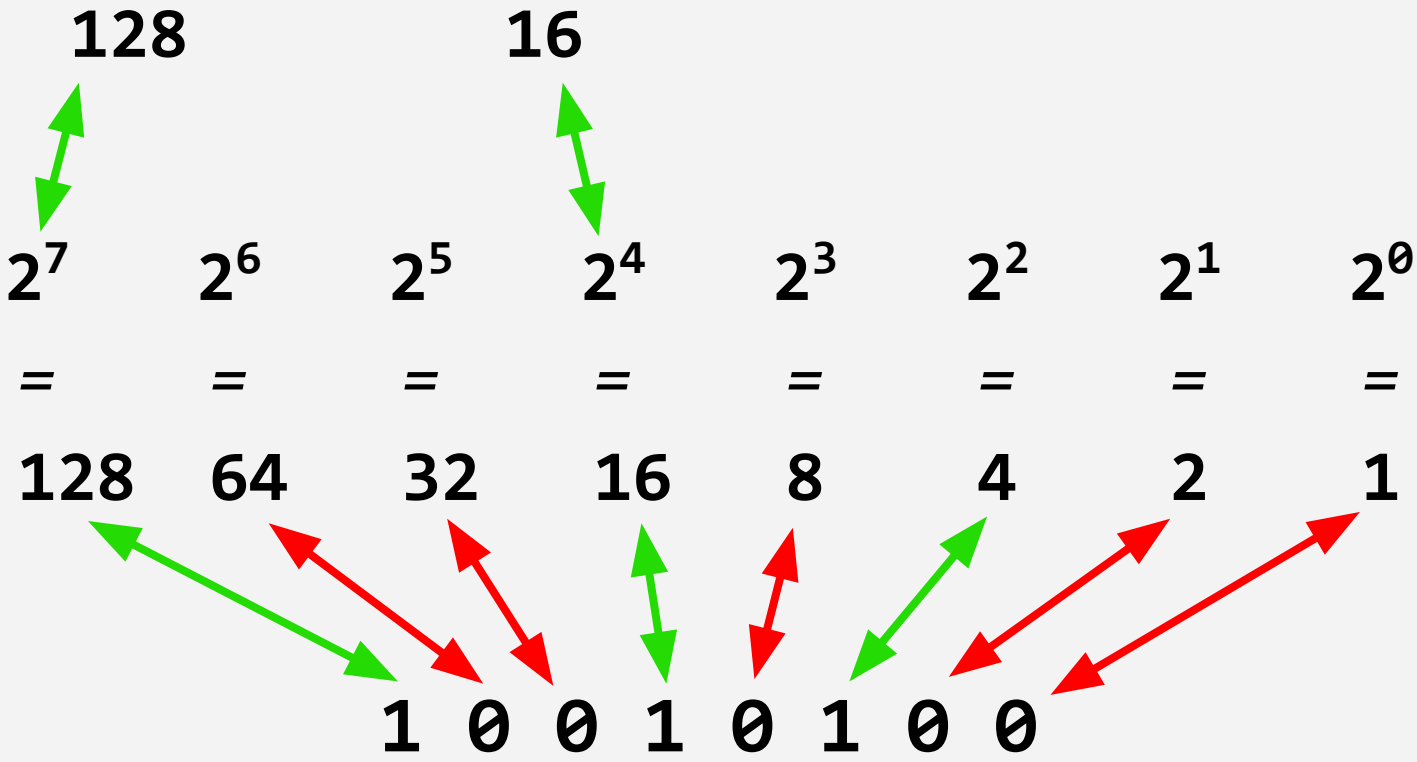
# How do we go from binary to decimal?



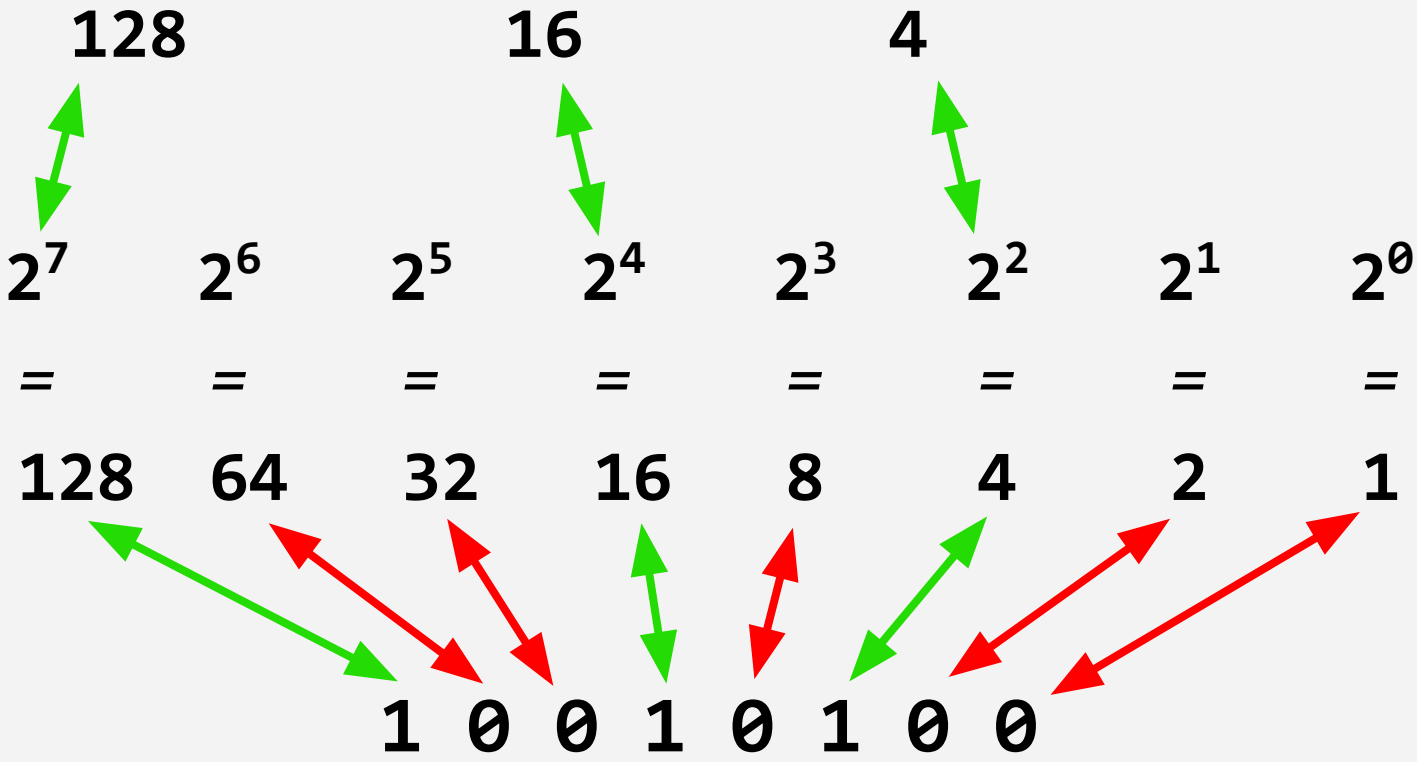
# How do we go from binary to decimal?



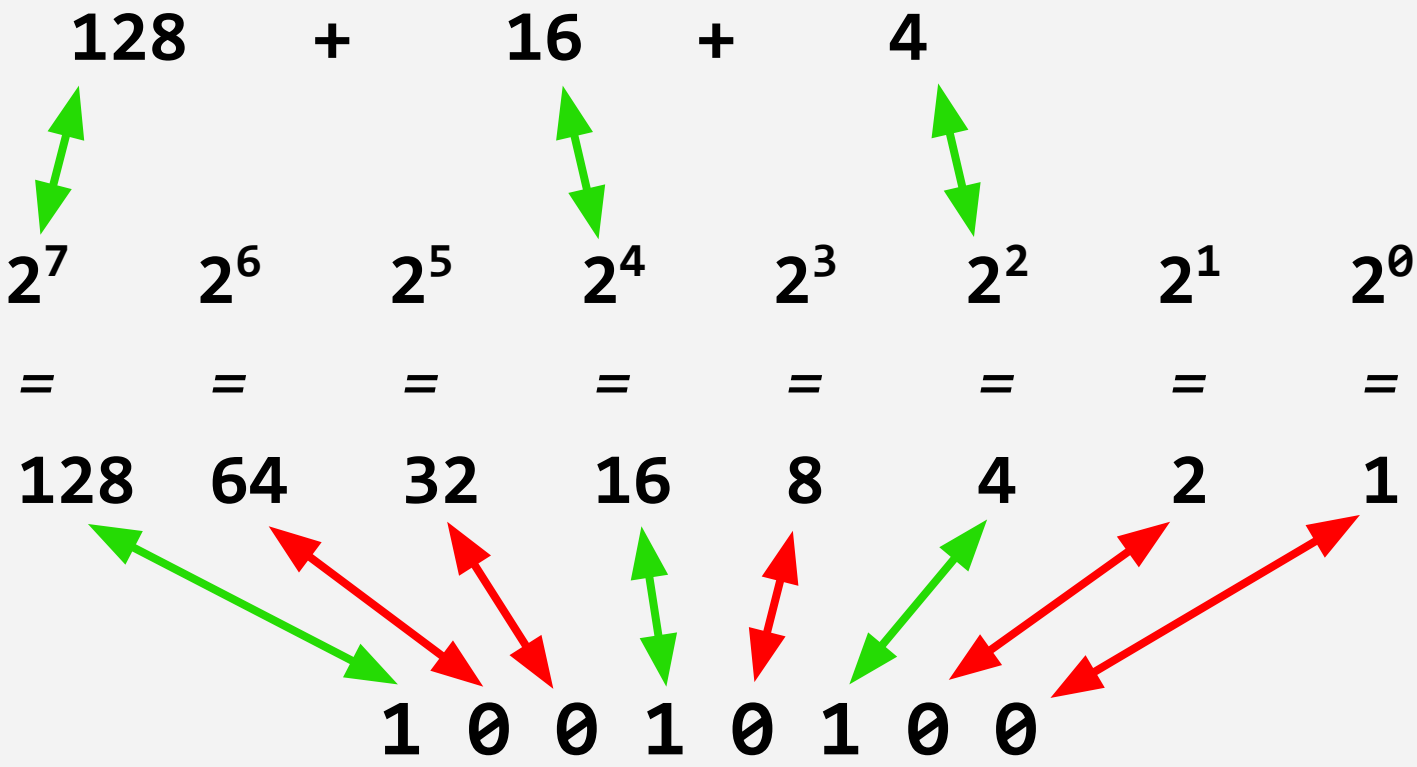
# How do we go from binary to decimal?



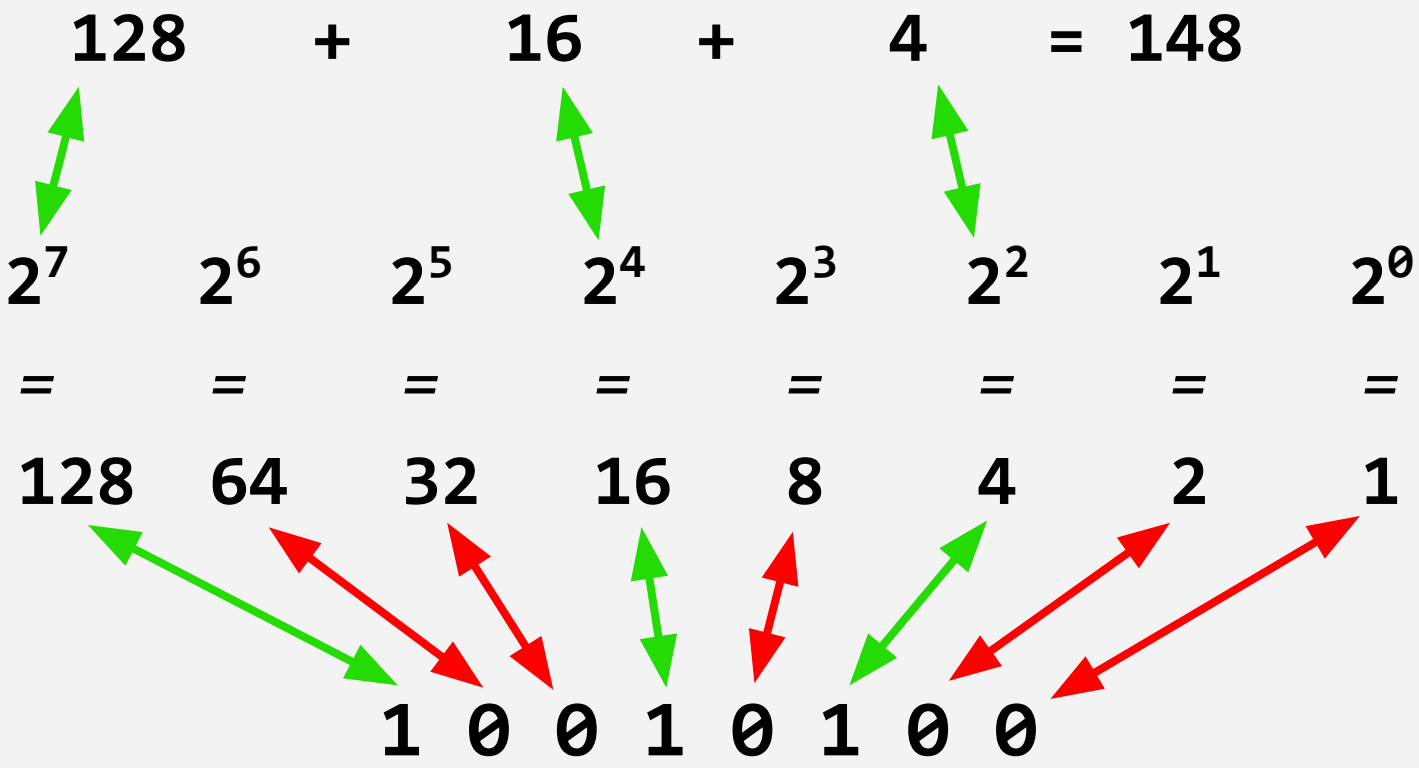
# How do we go from binary to decimal?



# How do we go from binary to decimal?



# How do we go from binary to decimal?



# Convert from Binary

- Middle: **`1010111`**
- Sides: **`0011111`**

# Convert from Binary

- Middle: **`1010111`** **`87`**
- Sides: **`0011111`**

# Convert from Binary

- Middle: **1010111** **87**
- Sides: **0011111** **31**

# Binary Conversion

- What if we want to convert a larger number?

# Binary Conversion

- What if we want to convert a larger number?
  - **Middle:** 787 to binary
  - **Sides:** 515 to binary

# Binary Conversion

- What if we want to convert a larger number?
  - **Middle:** 787 to binary `1100010011`
  - **Sides:** 515 to binary

# Binary Conversion

- What if we want to convert a larger number?
  - **Middle:** 787 to binary `1100010011`
  - **Sides:** 515 to binary `1000000011`

# Large conversion

**Middle:** `1010101011011101`

**Sides:** `1110110111100100`

# Large conversion

**Middle:** `10101 01010 11101`

**Sides:** `11101 10111 00100`

Large conversion

**Middle:** `10101 01010 11101`

**Sides:** `11101 10111 00100`

`21853`

Large conversion

**Middle:** `10101 01010 11101`

**Sides:** `11101 10111 00100`

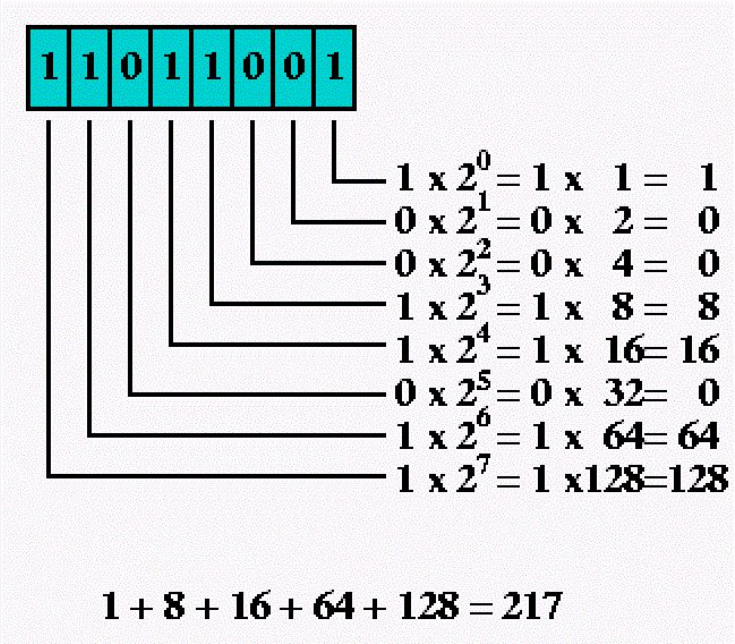
`21853`

`30436`

# Converting from Binary

- Take an 8-bit binary string as input
- Print out the resulting decimal number
- For instance:

```
Enter binary number:
10101010
Decimal: 170
```



```
binary_string = input('Enter binary number:\n')
```

```
binary_string = input('Enter binary number:\n')

decimal_number = 0
i = ???
while i >= 0:
    ## What goes here?
```

```
binary_string = input('Enter binary number:\n')

decimal_number = 0
i = ???
while i >= 0:
    ## What goes here?

print('Decimal:', decimal_number)
```

Activity

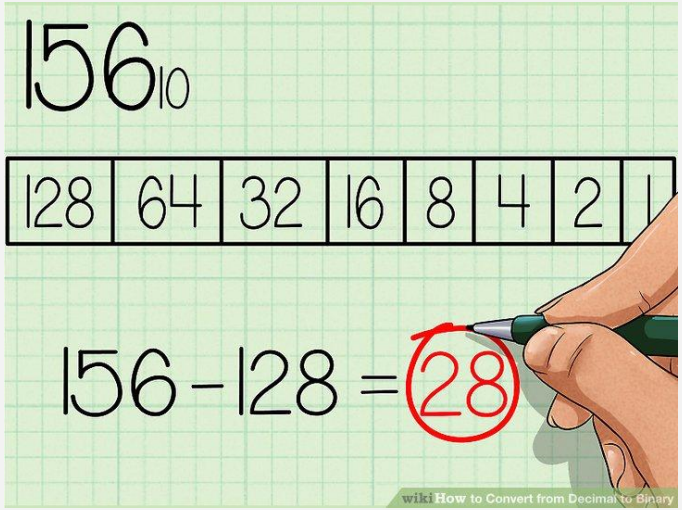
```
binary_string = input('Enter binary number:\n')

decimal_number = 0
i = ???  ## What should i start at ?
while i >= 0:
    ## What goes here?

print('Decimal:', decimal_number)
```

```
binary_string = input('Enter binary number:\n')

decimal_number = 0
i = len(binary_string) - 1
pow = 0
while i >= 0:
    if binary_string[i] == '1':
        decimal_number += 2 ** pow
    pow += 1
    i -= 1

print('Decimal:', decimal_number)
```

# Converting from Decimal

- Take a decimal integer as input (max 255)
- Print out the resulting binary string data
- For instance:

```
Enter Decimal number less than 256:
125
Binary: 01111101
```



```
decimal_number = int(input('Enter Decimal number less than 256:\n'))
power = 7
binary_string = ''
while power >= 0:
    # What goes here?
    power -= 1
print(binary_string)
```

**Activity**

```
decimal_number = int(input('Enter Decimal number less than 256:\n'))
power = 7
binary_string = ''
while power >= 0:
    # What goes here?
    power -= 1
print(binary_string)
```

```
decimal_number = int(input('Enter Decimal number less than 256:\n'))
power = 7
binary_string = ''
while power >= 0:
    power_val = 2 ** power
    if decimal_number >= power_val:
        binary_string += '1'
        decimal_number -= power_val
    else:
        binary_string += '0'
    power -= 1
print(binary_string)
```

```
decimal_number = int(input('Enter Decimal number less than 256:\n'))
power = 7
binary_string = ''
while power >= 0:
    power_val = 2 ** power
    if decimal_number >= power_val:
        binary_string += '1'
        decimal_number -= power_val
    else:
        binary_string += '0'
    power -= 1
print(binary_string)
```

***What would happen if the input was 2000 ?***

# Write the code on the whiteboard

- Write a program that
  - Accepts a binary number (not just 8-bit ones, any length) as input
  - Reports to the user how many 1's and 0's were in the string
  - For example:

```
Enter binary number:
1101011101010000010
    1s: 9
    0s: 10
```

```
binary_string = input('Enter binary number:\n')
count_0 = 0
count_1 = 0

### What goes here?

print('    0s:', count_0)
print('    1s:', count_1)
```

```
binary_string = input('Enter binary number:\n')
count_0 = 0
count_1 = 0
i = 0
while i < len(binary_string):
    if binary_string[i] == '0':
        count_0 += 1
    elif binary_string[i] == '1':
        count_1 += 1
    i += 1

print('    0s:', count_0)
print('    1s:', count_1)
```

```
binary_string = input('Enter binary number:\n')
count_0 = 0
count_1 = 0
i = 0
while i < len(binary_string):
    if binary_string[i] == '0':
        count_0 += 1
    elif binary_string[i] == '1':
        count_1 += 1
    i += 1
    # LOCATION
print('    0s:', count_0)
print('    1s:', count_1)
```

Loop table for **i** , **count_0**, and **count_1** based on this location, for input:

**1010**

```
binary_string = input('Enter binary number:\n')
count_0 = 0
count_1 = 0
i = 0
while i < len(binary_string):
    if binary_string[i] == '0':
        count_0 += 1
    elif binary_string[i] == '1':
        count_1 += 1
    i += 1
    # LOCATION
print('    0s:', count_0)
print('    1s:', count_1)
```

| i | count_0 | count_1 |
|---|---|---|
| 1 | 0 | 1 |
| 2 | 1 | 1 |
| 3 | 1 | 2 |
| 4 | 2 | 2 |

# Write the code on the whiteboard

- Write a program that
  - Accepts a string of digits as input
  - Outputs them like so:

```
Enter string of digits
12501103
1 -> 2
5 -> 0
1 -> 1
0 -> 3
```